WIKITEXTBOOKS: DESIGNING YOUR CLASS AROUND A COLLABORATIVE WRITING PROJECT

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Abstract: The authors have used wiki technology to support large-scale, collaborative writing projects in which the students build reference texts (called WikiTextbooks). The goal of this paper is to prepare readers to adapt this idea for their own classes. We give examples of the implementation of and outcomes from WikiTextbooks in a variety of courses, including lecture and discovery-based classes. We discuss the kinds of challenges that WikiTextbooks address and focus on critical design decisions. Finally, we conclude with a suggested wiki project that is approachable for new users and appropriate for most course structures.

Keywords: course design, wiki, technology, Moodle, textbook, blended courses, collaboration, writing

1 INTRODUCTION

We have used many different kinds of collaborative student writing assignments in our courses. These assignments have had positive effects on student learning, but they introduced new logistical difficulties. Typically, these assignments required that the students work from one master document. This requirement made it hard for the students to collaborate unless everyone was present, and sometimes information would be lost when conflicting drafts were saved. In addition, some students found LaTex documents onerous to use. We, as instructors, typically saw only final drafts, and it was difficult to tease apart the individual student contributions. Finally, we had hoped that these assignments would produce useful, living documents, but the students rarely returned to them after submission.

The advent of cloud technologies like GoogleDocs and Dropbox offered interesting solutions to some of these logistical difficulties. In particular, Wiki technology offers solutions to all of these difficulties and presents exciting opportunities for massively multi-user online groupwork. For those unfamiliar with the technology, a wiki is a website with

multiple authors and creators. Peterson [9] gives a nice description of the key features of a wiki, which we summarize. Wikis allow for online and collaborative authoring. The mechanics of page creation and authoring are stream-lined, as is mathematical typesetting, like LaTex; it is often possible to see all versions of a page and track the changes between them. Hyperlinking between the pages is made easy or automatic.

Wiki technology has emboldened us to design courses around a single collaborative student writing project that encompasses all course content, engages all students, and spans the entire term: the students build a textbook. Because we ask our students to build this textbook using wiki technology, we call it a *WikiTextbook*.

This journal has published articles that describe courses with a student-written textbook [1] and courses with a wiki [9]. In this paper, we extend these articles in two ways. First, WikiTextbooks combine the ideas of wikis and student written texts, so our examples give further illustrations of the ideas therein. Second, we step back from the examples to focus on course design more explicitly. We frame the discussion of course design that uses WikiTextbooks as a response to the design challenges created by (i) the student learning objectives and (ii) existing structural dilemmas in the course. By the end of this paper, you will have ideas about how you could design a course around a WikiTextbook.

- In Sections 2, 3, and 4 we begin by giving examples of three classes with design challenges and the WikiTextbooks we built in response; we also give some data about the outcomes in these classes. Our successes and missteps in these examples inform the conclusions we make in Section 6. These examples come from courses that are lecture-based (Section 2), exploration-based (Section 3), and inquiry-based (Section 4).
- In Section 5 we step back from the examples to connect WikiTextbooks to course design challenges more generally.
- In Section 6, which is the heart of this paper, we discuss critical design decisions when implementing WikiTextbooks.
- And in Section 7 we offer a starting point that will help you to design a course around a wiki project for the first time. We have realized this starting point as a wiki [10] for our readers.

The three detailed examples of WikiTextbooks below come from small courses (7-18 students), but the design principles scale up to very large courses. Buckland [2] gives an inspiring talk with examples of wiki design in courses with 60-600 students.

Wikis and Moodle

Our courses all used versions of the online course management system, Moodle, which has built-in wiki capability. (We have also built wikis using PBWorks [8, 10], which is free for educational purposes.) The wiki in Moodle allows for embedded images and LaTex code with very little technical overhead. Moodle automatically restricts access to the people associated with the course by requiring a campus login. The Moodle wiki saves copies of every version of every page, including author information and a time-stamp; the wiki will display differences between versions and is searchable. Section 6 contains some thoughts on familiarizing students with wiki technology.

2 CALCULUS II, LECTURE-BASED

Context

This section describes a Calculus II course that I taught during the Spring of 2011 at a small liberal arts college. There were 9 students in the course, all first-years and sophomores who intended to major in STEM or STEM Education fields. The students purchased and used *Calculus: Single and Multiple Variable* by Hughes-Hallett et al. [6].

The course was lecture-based with elements of active learning. I generally lectured on Mondays and Wednesdays. On Tuesdays and Fridays, class would start with 1-3 student presentations of prepared problems, and then the students would work on and discuss worksheets of practice problems.

Design

The content goals for this course are determined by the department to include techniques of integration, applications of integration, and power series. I have one additional learning objective for the students.

- The students should develop the habit of generalizing and abstracting from examples.

The skill of generalizing is critical for the students in their future work, but it also critical for the students' success in this course. The content of this course can be extremely technically demanding, especially when the students are struggling with algebraic and abstract notation; generalizing from examples reduces the amount of material that must be memorized and draws their attention from the algebra back to the concepts. So the design challenge for this course is to find ways to support the students as they generalize and to find ways to encourage the habit

of abstraction. I set up the WikiTextbook to address this design challenge by (1) giving the students opportunities to pare examples down to their most essential features (abstract) and (2) providing examples from which they can generalize.

The WikiTextbook contains three main components: lecture summaries, detailed examples, and questions. One student per lecture used one or more sets of notes from lecture to build a lecture summary page in the WikiTextbook. The student had a few days to produce a first draft of this page, and then we would meet individually to discuss the draft. These discussions focused on (i) how to identify and select the important patterns and (ii) how to choose examples that support an understanding of those patterns. The student then had a few days to revise the lecture summary page in response to our conversation.

Recall from above that class started on Tuesdays and Fridays with student-presented problems. These presenters were expected to build a page with a detailed solution of their problem and link it to the corresponding lecture summary page. In addition to a solution, students were expected to include explanations of important steps, so the write-ups resembled examples from a textbook. However, in comparison to traditional textbook examples, the students were expected to expand more on why they had *chosen* to do those steps.

Finally, as each exam approached, the students were asked to post questions at the bottom of multiple lecture summary pages about the content therein; they were also asked to answer at least one question asked by someone else.

Outcomes

The goal for including the WikiTextbook in the course was to support generalization and to encourage the development of the habits of abstraction and generalization.

- My discussions with the student authors of the lecture summary pages were the best part of the course. These discussions provided an opportunity for the student author to abstract from the examples in the lecture to more general approaches. The students often commented that the process caused them to learn how to take notes in lecture. The students performed more highly on the quizzes and exam problems related to the content that they added the the Wiki-Textbook. So authoring a page appears to have helped the student abstract/generalize in one particular topic, but that skill may not have transferred fully to other topics.
- All of the exams had take-home components, and the students had access to the WikiTextbook and the purchased textbook during

> these components. All of the students used the WikiTextbook extensively during the take-home exams. Several reported that it was much easier for them to get ideas from the WikiTextbook than the purchased textbook. This indicates that the students were trying to extend existing solutions instead of looking for algorithmic instructions for techniques. However, there was some evidence that the presence of the WikiTextbook convinced a couple of students that they could search for information during the take-home exam instead of studying in preparation for it.

I think the WikiTextbook was particularly good at helping the students see the commonality among the applications of integration (e.g. volumes of revolution, arc length, and total pressure computations). These applications are too large for the students to hold in their working memory simultaneously, so the written examples in the WikiTextbook were critical.

I was happy with the effects of this WikiTextbook design, and the students were positive about the experience as well. However, almost every addition to the WikiTextbook required administrative action on my part. It was also a struggle to get the content into the wiki fast enough for it to be helpful to anyone but the student author. I solved some of these administrative issues before designing the course described in Section 4; there are other lessons learned in Section 6.

3 VECTOR CALCULUS, EXPLORATION-BASED

Context

This section describes an honors vector calculus course that I taught in the Spring of 2012 at a large comprehensive state university. The class consisted of 18 students - all were freshmen who had scored a 4 or 5 on the AP Calculus BC exam (or some equivalent criterion).

The course is a special section, structured around exploration projects that help students discover and define vector calculus concepts organically. There was almost no instructor lecturing, no textbook, and the use of outside resources was forbidden as these activities would undermine the discovery process. Each week I would hand out a new project that consisted of a series of problems focused on a particular topic. For example, the students constructed clay models of functions (complete with parametrized curves) and answered a series of questions about their models that grounded their thinking so they could then derive the multivariable chain rule. Subsequent problems ranged from traditional computational problems to deep conceptual questions. Class time was spent on small-group conversations about these problems, student pre-

sentations of solutions, and whole-class discussions. We call this course structure exploration-based.

A large percentage of the students' work each week consisted of producing type-set solutions in pairs to selected problems from the projects, and students were also given the opportunity to correct and resubmit their solutions once they had been graded and returned. Heavy emphasis was placed on students explaining their methods, both orally and in writing.

Design

I had taught several exploration-based courses; and while I considered these courses successful, the structure led to some design challenges.

- Without a textbook or access to outside sources, my students had trouble keeping track of the large body of material we generated in class.
- There was not enough cause for students to synthesize the knowledge they gained, reflect on the goals of individual projects, or connect ideas across projects. Typesetting collaborative solutions to challenging problems for homework did promote a deep understanding of material, but that understanding was compartmentalized in some sense.
- I wanted to help the students improve their writing.

The basic set-up of the project was simple - the students did all of the writing and editing, while I provided editorial feedback. Each weekly exploration project corresponded to a chapter in the WikiTextbook. I assigned 2-3 student authors for each chapter and these authors were responsible for determining what content to include as well as how to divide the writing duties. Authors wrote in the wiki in lieu of collaborative homework for that particular week. I provided editorial feedback (in the wiki) and a tentative score the day after the chapter was due. The authors then had one week to respond to my feedback, at which time I would re-evaluate their work and update their score.

One week after the official due date, the chapter was open for editing from any student in the class. Students were required to write a peer review (of the mathematics, the exposition, and the grammatical details) of any chapter they wished to edit before making significant changes, and bonus credit was awarded for substantial edits or additions.

Outcomes

While the WikiTextbook project was not a failure, it was not the success I hoped it would be. The WikiTextbook itself was uneven. Roughly a

third of the class did truly impressive work, most did fine work and a few barely contributed. To better understand how the students responded to the WikiTextbook project (and other aspects of the course) I collected survey data from them weekly and followed up with an in-depth exit survey at the end of the course. This data, in conjunction with my observations of the students and their work, has led me to the following conclusions about how well this WikiTextbook addressed the structural dilemmas listed above.

- A few students felt the WikiTextbook was a very valuable reference text, but the majority of the class did not use it much. Regular surveys indicate that on average three students used the WikiTextbook each week and often only one student found it especially helpful. In general students felt that while it was nice to have an easy-to-navigate reference tailored to the course, they found the uneven quality and occasional omissions frustrating.
- The class did not harness the power of the wiki format to synthesize and connect the material as I had hoped they would. Most students wrote a cursory chapter summary and only hyperlinked to other sections after being prodded in my feedback. In several cases students took great care in writing expository material for their peers, and in these cases the wiki provided an opportunity to reflect on a particular concept. However, other entries did not indicate much reflection at all.
- I had hoped that the students would read critically as part of the peer review process and that this critical reading would be the tool that improved their writing. Most students did not take the opportunity to do a peer review. A handful of peer reviews did touch on exposition, notation, and organization issues - indicating that the project at least brought these issues to the table. However, they generally seemed reluctant to say anything substantial about another student's writing or to alter another student's entry - a natural hurdle that we never managed to overcome.

Although the WikiTextbook project did not successfully resolve the design challenges that inspired its creation, I am pleased to report that it did cause some truly impressive work. Several students wrote contributions that demanded a deep and nuanced understanding of the material and required them to employ effective visualizations and trace concepts back to foundational single-variable calculus ideas. Our WikiTextbook contained a beautiful proof of the chain rule, an excellent description of how a gradient dynamical system leads to the second derivative test for multivariable functions, and a fantastic proof of Green's Theorem.

Certain aspects of the design of this WikiTextbook led to these mixed results. The kinds of work required for the WikiTextbook overlapped with other types of work the students were doing, which may have reduced the energy they put into the WikiTextbook. The quality of the WikiTextbook was uneven, and thus it was a less useful resource for the students. The design of the WikiTextbook project also made it possible for students to treat it as an individual responsibility. As a result, many of the students approached the work for the WikiTextbook as isolated assignments and did not harness the power of the technology to create a cohesive document. Furthermore, this compartmentalized work may have undercut the usefulness of the wiki work in my students' minds. In the exit survey I asked students to list the types of work that contributed to their learning gains in several different categories. In each case only one or two students listed the wiki project as contributing to their progress in that category, indicating that they found other aspects of the course more helpful. I plan to try the WikiTextbook project again, but next time will employ several of the lessons I learned this time, which we have detailed in Section 6.

4 MODERN GEOMETRY, INQUIRY-BASED

Context

This section will describe a Modern Geometry course that I taught during the Spring of 2012 at a small liberal arts college. Modern Geometry is a proof-based course, and the students have taken 2-4 proof-based courses before it. During the Spring of 2012, there were 7 students in the class; 5 students were pre-service teachers.

The course was structured in the tradition of the "modified Moore method". There was no textbook for the course; in fact, the students were forbidden from using external resources like books and the internet. In place of a textbook, the course was structured around a sequence of theorem statements and problems from the "packet" written by David Clark [3]. In preparation for class each day, the students would prepare proofs or solutions for the next $\approx$6 items from packet. Each day, class began with the students in small groups at the boards, sharing solutions and preparing to present them to the rest of the class. The majority of class time was spent presenting, discussing, and polishing these solutions. We call this course structure inquiry-based.

Design

I have three central learning objectives for the students in Modern Geometry.

- The students should add coherence, connectivity, and perspective to their existing Geometry content knowledge.
- The students should internalize the axiomatic method of mathematics and the accompanying values and beliefs about mathematics and mathematical truth.
- The students should raise the quality and precision of their communication.

These learning objectives form the design challenges when combined with the two main structural dilemmas in the course. (1) Euclidean Geometry contains a very large number of small results; this volume makes the coherence and connectivity hard to see, and it obscures the axiomatic method. (2) Most of the results are familiar to the students from high school; this familiarity can interfere with the perspective as well as the axiomatic development, and it makes it harder for the students to write at a college level.

The structure of the WikiTextbook tasks described below has evolved through several iterations, and that evolution was guided by these design challenges. As a result of this evolution, the details have become intricate. I think of myself as the Publisher/Reviewer for the manuscript that the class is hoping to publish. I represent an external standard for quality, but the students retain the role of Authors throughout.

Recall that most of class time was spent with the students presenting the theorems that they had proved in preparation for class. Before the next class meeting, the students were expected to publish something substantive from class to the WikiTextbook. This posting usually involved (1) adding a theorem statement to the chapter page and creating a new page for its proof, (2) in the new page, writing a polished version of the proof of the theorem, and (3) distilling the proof into a summary of the clever ideas, which was placed under the statement of the theorem in the chapter page.

In addition to the thrice-weekly publishings of new content described in the previous paragraph, the students were expected to contribute weekly to the quality of the WikiTextbook through some editorial work. These contributions included (a) filling a hole left by a previously skipped item, (b) revising proofs, images, or summaries in response to feedback, (c) adding extra material (like a discussion of equivalence relations, which is not explicit in the packet), (d) adding motivating commentary between the theorem statements, and (e) any other student-generated initiative to improve the document. Eventually, this editorial work also included the task of writing summaries at the section and chapter level and signing off on the quality of portions of the document.

I evaluated these weekly and thrice-weekly individual contributions and assigned grades that indicated the quality and precision of the writ-

ing, the appropriateness of the images, the construction of the summary, and whether or not the contributions were substantive enough. Once per week, I read the entire WikiTextbook (except for the proofs) and assigned the entire document a collective grade. The students knew from the start of the term that the final collective grade on the WikiTextbook would determine the majority of their course grade. I posted general feedback about themes in the writing. The feedback was not directive; I indicated concerns but offered minimal or no explicit ways to address these concerns.

The course was designed so that the development of Euclidean Geometry was complete with 30% of the term remaining. The daily publishing work then transitioned to daily revision work. This portion of the term was explicitly set aside for other activities that leverage the potential of the WikiTextbook for reflection. Here are some of the tasks that I think would have been difficult or less effective without the WikiTextbook.

- We explored a model of Hyperbolic Geometry. The students picked the axioms that Hyperbolic and Euclidean Geometries share (i.e. axioms for Neutral Geometry) and used them to build an Appendix in the WikiTextbook that classified our results as Neutral or Euclidean (and they added a few Hyperbolic results).
- The students constructed a visual representation of the logical relationships between the items in the WikiTextbook. The wiki is capable of generating a list of all pages linking to a given page, which allowed the students to build a directed graph out of the pages/theorems; the challenge was to organize this massive web to communicate its structure.
- The students reread examples of their own writing, including multiple versions of the same page. They reflected on and documented how much and in what ways they had developed as writers.
- We read *Incompleteness* by Rebecca Goldstein [5], a biography of Kurt Gödel that discusses implications of the axiomatic method. The students wrote reflections on these readings in the wiki; and these reflections eventually became a Forward to the WikiTextbook that articulated a perspective on the nature of mathematical truth. I think that the WikiTextbook, which served as a concrete example of an axiomatic system, was essential for helping the students understand these subtle themes.

Outcomes

I surveyed and interviewed the students about their experiences in the course, and their reports match my observations.

- The students reported that the act of hyperlinking the items in the

WikiTextbook added dramatically to the coherence and connectivity of their Euclidean Geometry content knowledge. They reported that the revision, summary, and Appendix work were valuable for adding perspective to their understanding of Euclidean Geometry.

- The students developed a more nuanced understanding of the nature of mathematical truth and internalized the axiomatic method. They also seem to have come to accept that human choices play a role in the development of mathematics, particularly in the form of axioms. The students reported that the revision work and the discussions of *Incompleteness* were critical for these changes.
- The quality of the student writing rose dramatically during the term. The students reported that having the end-goal of a textbook that they had created was critical for maintaining the motivation to keep revising their work.

I'll close this section with some of the other themes that arose in the surveys and interviews. The students reported that they spent a greater proportion of their time in this course doing high-level tasks (Analyzing, Evaluating, and Creating) than in their other courses. They connected this experience with the WikiTextbook by pointing to the work of summarizing proofs, determining for themselves if a page was complete, and building a book collaboratively. The students reported that they are proud of the WikiTextbook. The pre-service teachers reported that they expect to use the WikiTextbook in their future careers. One student even mentioned discussing it at a job interview with an impressed interviewer.

5 WHY WIKITEXTBOOKS?

Other authors have written about the benefits of students building a textbook and of using online collaborative environments [1, 4, 9]. We would like to enter this conversation by carefully articulating *how* the student learning objectives for our courses and other dilemmas created by existing course structures connect to our design decisions. We believe that asking students to build a WikiTextbook provides an opportunity to accomplish many of these objectives and to address many of these dilemmas. We will organize the student learning objectives as knowledge, skills, and dispositions. These objectives are general and present in all of our courses.

Knowledge:

- Regardless of the content goals for a course, students should develop a deep understanding of the course topics.

- The students' understanding of the course topics should be connected and interrelated.

Contributing to a WikiTextbook provides an opportunity for deep engagement with the content, and hyperlinking encourages a less linear and more interconnected understanding.

Skills:

- Students should communicate their ideas clearly, thoroughly, effectively, and appropriately. Towards this end, students should revise their written communication.
- Students should collaborate effectively and appropriately.
- Students should use the resources available to them effectively and appropriately. Students should evaluate ideas critically.

Building a WikiTextbook provides many opportunities for students to write and revise; moreover they must write carefully because they are writing for their peers and future selves, not an expert. Wikis facilitate collaboration; large tasks like building a WikiTextbook can motivate collaboration. Finally, because a WikiTextbook is student-authored, it encourages readers to use it in conscious and critical ways.

Dispositions:

- Students should feel that they have taken ownership of the course material and that they are the experts and authorities for portions of the content.
- The students should come to believe that mathematics is a human endeavor and is changing through time.

WikiTextbooks make the construction of knowledge visible and communal yet still personal.

Other Structural Dilemmas:

- Students should process discussion from class.
- Students should spend time reflecting and synthesizing.
- Feedback should not require an in-person hand-off.
- When appropriate, student work and the feedback on it should be available to other students. This feedback should be more than a teacher-student dialogue; it should be a teacher-student-student conversation.

The WikiTextbook designs described above explicitly ask the students to keep thinking about class after it is over. And wiki technology offers new and exciting ways for information to flow outside of the classroom.

5.1 WikiTextbooks and Discovery-Based Learning

The authors teach a variety of exploration-based and inquiry-based courses. We group these types of courses together and call them discovery-based courses because the students generally discover the main results instead of having those results explained to them through lecture. Discovery-based course design has some unique challenges, and we think WikiTextbooks are especially useful for addressing these challenges.

- Speaking and group work are the primary focus in a discovery-based classroom. WikiTextbooks balance this focus with emphasis on asynchronous writing. This balance is particularly appealing to shy students who may under-perform in public.
- There is no reference text in a discovery-based course because it undermines the students' motivation for invention. A WikiTextbook collects the discoveries and serves as a reference.
- Feedback must be extremely timely in a discovery-based course because each step is a step into the unknown for the student. Wikis allow the instructor access to the current draft of a student's work at any time through the internet.
- Holes in understanding sometimes go unfilled in discovery-based courses because the students are always working on new discoveries. Building a WikiTextbook asks students to organize and solidify their discoveries. This can make holes transparent, but it is also an important tool for finding new directions for inquiry and exploration.

6 WIKI-COURSE DESIGN

In the previous section, we described the kinds of design challenges that cause us to include WikiTextbooks in our courses. But simply adding a wiki to a course is insufficient for the kinds of benefits that we desire. The benefits come from the work done by the students, which gives them a significant amount of responsibility for their learning. Our experience has taught us that the students will need answers to fundamental questions about the WikiTextbook (who, what, when, where, why, and how) and that these answers should be integrated into the design of the course. In this section we explain these student questions and share ways to provide them answers, with references to our own missteps and successes in the examples from Sections 2, 3, and 4.

6.1 Why?

The students need to have a reason for using the wiki and contributing high quality content to the wiki. If the product is not high quality, then

the students will see that using and contributing to the WikiTextbook is not valuable, further reducing their motivation (see Section 3). Moreover, students who are motivated to engage with the WikiTextbook are significantly less likely to use resources inappropriately or to cheat. You can create two main types of motivation for students to engage with a WikiTextbook; it can be the unique solution to an individual need, and it can be part of a general communal need.

For a few students, the love of the material or the enjoyment of creating will be all the reason needed. For the rest, there are many ways to set up individual needs and frame a WikiTextbook as the unique solution to those needs. The most obvious way is to make individual contributions part of the student's grade (the subtle consequences of this approach are discussed below). You could also allow the students access to the WikiTextbook during their exams, or you could allow them to quote only those results that are part of the WikiTextbook. The WikiTextbook can be sold as a personalized reference that can be exported and kept (see Section 4).

Stepping back even further from grades, you can convince the students that working on the wiki is valuable by explicitly connecting that work to the learning objectives. It's critical for this argument that the work on the wiki be distinct from the other work being done by the students. For example, in Section 3 we detail how overlapping tasks undermined the value of the wiki in Vector Calculus. Similarly, the WikiTextbook could be the only resource that will make the structure and organization of the course content visible to the students. For example, the wiki in Calculus II in Section 2 was designed to help the students see the commonalities among the applications of integration.

In addition to the students' individual needs, general communal needs play a vital role in the success of a WikiTextbook. The feeling that the contributors to a wiki are "in it together" and hence are responsible for carrying their weight and taking initiative is sometimes called "WikiNature". The simplest way to generate WikiNature is to make each student responsible for the product as a whole and make sure it is too large for an individual student to build alone. We learned from the Vector Calculus wiki in Section 3 that making each student responsible for an isolated section of the final product squashes WikiNature. It is also important to bring the WikiTextbook into the classroom: refer to it regularly, display it at critical moments, and use it to answer questions when possible. When a student has authored a page, they have become your local expert; ask them to serve as that expert in the classroom. Do your best to make sure there is exceptional work done early in the term, and praise that work publicly.

Whatever motivations you choose to build into your course design, you will need to keep emphasizing them for the students regularly. Talk

with students about the causes of their learning and about the understandings that you don't think would have been possible without it. And do something with the wiki that could not have been done otherwise (see Section 4); use the technology to share information differently, to connect it through hyperlinking, and track its changes through versioning.

6.2 How?

Once the students believe that they should build the WikiTextbook, they will want to know *how* they will accomplish such an enormous task. Before the students can understand how they will build a WikiTextbook, they need to be able to imagine the final product. We suggest that you build the skeleton of the wiki before the term begins and ask the students to explore it on the first day. The skeleton should include enough pages to convey the large-scale structure of the wiki and a MainPage that describes the kinds of information that will be included in it. We describe a concrete example of a skeleton below in Section 7, or you can see this skeleton directly [10].

You will need to communicate to the students that they will be both generating content for the WikiTextbook and revising that content. The easiest way to accomplish this is to make each type of work an explicit assignment, as was done in the Geometry wiki in Section 4. The students will probably be intimidated by the prospect of generating the content for the WikiTextbook, and they will be particularly intimidated if they have to write about content that they don't yet understand. So we recommend that you give assignments that ask the students to process the discussion from class, and these assignments should produce the content of the WikiTextbook. In Modern geometry (Section 4), we further reduced their stress levels by audio-capturing the class discussions with a LiveScribe pen [7].

To clarify the process of revision for the students, you should give examples of changes that establish the difference between surface edits and substantive revisions like connecting disparate pieces into a whole and identifying and filling gaps in the document. We also recommend that you model these kinds of work explicitly in class, especially responding to feedback on the existing content. It can be helpful to produce a "Code of Conduct" for the students that establishes appropriate collaborative behaviors, including what to do with feedback, how to edit their peers' work, and how to decide collectively when work is finished.

6.3 What/When?

In the previous subsections, we have discussed ways to help the students understand *why* they are building a WikiTextbook and *how* that task

will be accomplished. The next natural questions for them to ask are exactly *what* they should be doing and *when* they should do it. In short, a successful WikiTextbook requires establishing productive and appropriate work habits.

Doing a small amount of work on the WikiTextbook should be a regular part of the student's life. At a minimum, we recommend that the students contribute something (new content, revisions, feedback) to the WikiTextbook every week, though every 1-2 days is best. It's important that, for the majority of the term, this work involves both generating new content and revising existing content, although it can be good to leave some time at the end for the class to focus on larger-scale revisions (see Section 4).

It is also important that certain work behaviors become habits. Encourage students to draft in the wiki so that the final step before submission isn't just typing. It is also important that the students' initial drafts be expected to include certain structures automatically. Pages should be named systematically and consistently. If the pages are organized into folders, correct placement should be part of the creation habit. The appropriate terms should be hyperlinked in the first draft, and any other navigation should be built when the page is created. We suggest that you use the pre-built skeleton of the WikiTextbook to establish and communicate these procedures and that you monitor and direct the students to correct any errors early in the term. It is possible that the students will want to structure the wiki differently than you imagined, which is precisely the kind of creative work that we dream of, so you should forward these ideas to the class and praise the initiative.

The most powerful tools for establishing and shaping these work habits are the assessment, feedback and grading structures in the course. It turns out that the approach students take to WikiTextbooks is very sensitive to the grading structures in place, probably because of the scale and novelty of the project and the expected level of responsibility. There are two, very different ways to answer the grading question for WikiTextbooks because grading is a double-edged sword. On one hand, a grading structure that gives credit for work gives extrinsic motivation for that kind of work; on the other, such a structure can undermine WikiNature. Moreover, the decisions you make about grading depend subtly on how you've answered the question of *why* the students are building a WikiTextbook.

The grading structure should reinforce the student's understanding of the value of working on the WikiTextbook and should reinforce the habits needed for creating it. In any setting, we suggest giving a portion of the students' grades to the over-all quality of the WikiTextbook. If possible, make it clear that top marks on the over-all grade will require the students to show more initiative than just building the required

portions of the WikiTextbook. Do not grade the volume of work through the number of changes; grade the quality of the work. Consider using non-numeric scales so that you can communicate quality of work without the students thinking about it as accumulating points.

6.4 Who/Where?

The variety and volume of work involved in building a WikiTextbook could easily become overwhelming (see Section 2). In addition, the point of the wiki is to allow the students to take the lead, so you need to provide mechanisms for answering the questions of *who* and *where* that don't involve your attention or authority. The key is to give the students the power to manage the work themselves.

Our first recommendation is that working on the WikiTextbook should be a regular, standing expectation for the students. The timing of the assignments should be rhythmic (either in relation to the weekly schedule or organized around the class meetings), and the responsibility to remember these deadlines should be with the students. See Section 7 for an example. Make responding to feedback a regular part of the students' work, and place the feedback in a way that minimizes the hurdles to comparing it to the original.

Our second recommendation is to facilitate the students in self-organizing. Consider occasionally giving the students 5 minutes of class time to discuss administrative issues while everyone is present. Give the students space in the wiki to make "To Do" lists so they can "claim" content and communicate with each other about which items they are contributing or revising. Build these spaces so the students can discuss potential decisions, and empower the students to take these actions without any prior approval or setup from you. It should be the students' responsibility to tell you what they have contributed and what they want you to grade, and these pages can serve that purpose as well. Simply building spaces for self-organization is not enough to guarantee collaboration, but teaching the skills and habits of collaboration are outside the scope of this paper. However, the wiki helps you see the individual contributions, which allows you to give them feedback on their collaboration.

6.5 Getting Started

In this section, we have given advice on ways to design your course so that it provides robust answers to the questions that the students will have as they work on the WikiTextbook. The last crucial consideration is the very beginning of the WikiTextbook, which involves helping the students get the lay of the land and teaching them wiki technology.

Earlier, we suggested that the students be asked to explore the prebuilt skeleton of the WikiTextbook on the first day of class. However, simply exploring the skeleton of the wiki will not be sufficient for the students to learn the technology. We suggest that you demonstrate building and editing a page on the first day of class. We also suggest that you build several "tutorial" pages inside the wiki. These tutorials should include information on creating or editing a page, inserting images, and including mathematical notation. But for the students to start becoming comfortable with the technology, they need to build a page. In our experience, the students will be too stressed if their first page also requires them to worry about the new course content. We suggest that you have each student build a BioPage that includes (1) some autobiographical information, (2) an image of the student, (3) some mathematical notation, and (4) some reflection on their learning goals for your course. On top of teaching the technology and giving you access to the students' personal goals, this assignment establishes the public and student-owned nature of the project.

7 YOUR FIRST WIKI: A WIKIGLOSSARY

Our main objective in writing this article is to help readers successfully design a course around a large-scale wiki project. To that end we have generated an approachable starter-wiki design that can fit into many different course structures and a wide range of class sizes; it can easily be tailored to support the learning objectives of the course and perhaps to resolve structural dilemmas. We built a skeleton of the wiki for this project [10], which can serve as a starting point for your wiki and will illuminate the discussion below.

In trying to provide a more approachable wiki structure, we focus on the foundations of mathematics: definitions. We propose having the students build an annotated glossary as a wiki, which we call a *WikiGlossary.* We want to expand the notion of a glossary to include (1) a variety of examples and (2) both rigorous and student-generated, intuitive definitions. This idea is similar to a project sketched by Peterson [9]; here we flesh it out with details and discuss integrating it into your course. The previous section was structured around the questions a student would ask while building a WikiTextbook. An instructor would ask these same questions from a different perspective, so we give responses in a different order.

What/When?

No matter what math class you are teaching, your students will be exposed to new terms and concepts every day. In order to build a

WikiGlossary, we propose that you have your students add these items to the wiki. Each item should have its own entry page in the wiki that includes a precise definition (if appropriate), an informal definition that represents a student's understand of the item, and examples of the item. Contributing to the WikiGlossary should be a standing assignment; everyone should be responsible for creating or improving an entry after every class. The entries can contain multiple informal definitions, formal definitions from several sources, and many kinds of examples. In addition, the WikiGlossary can contain entries for relevant terms from prerequisite courses. These two types of flexibility allow the instructor to adapt the WikiGlossary for larger classes. The standing assignment could be slowed down to a contribution every week, but the work will probably come in spurts and the content will lag farther behind the course, reducing the usefulness of the WikiGlossary.

The schedule of your evaluations of the wiki will determine the pace of students' contributions, so you (or a TA) will need to look at these contributions on the same schedule as the assignments. Here is one idea for a manageable plan for individual assessment. Each contribution receives a mark in $\{0 = \text{none}, - = \text{weak}, \checkmark = \text{satisfactory}, + = \text{impressive}\}$, and the student's individual wiki contribution grade is determined by the *trajectory* of these marks over the term. Written feedback can be minimal and reserved for serious misconceptions. In addition to these regular assignments, the students could produce a portfolio of a small selection of their best contributions. Grading the trajectory emphasizes consistent contributions, and grading the portfolio emphasizes high quality contributions. The students should also have a communal wiki grade determined by the over-all quality of the WikiGlossary. You should provide a few sentences each week about the over-all quality, and you can give an estimate for this over-all grade to clarify your thoughts on its progress.

Who/Where?

In the previous section, we discussed what the students should contribute and when those contributions should happen. Here we discuss how the students know who is responsible for the content and where it goes.

First, the students should be responsible for collecting terms and concepts from class to add to the WikiGlossary; you should not have to produce an official list of new items before the students can work. Early in the term, consider giving them 5 minutes at the end of class to generate a list together. There should be a "To Do" page in the wiki, moderated by the students, that contains a list of items that need to be added to the WikiGlossary.

Second, the students should be responsible for self-organizing and

dividing up the work. The "To Do" page can also serve this purpose. Students can claim a piece of work by putting their names next to the items they wish to work on. This page can also include student discussion of needed revisions, not just needed entries.

Finally, the students should be responsible for communicating their contributions to you. For each assignment, create a page in the wiki where the students can list the work they did. Each student should provide a brief description of his/her contribution (for example "added new informal definition" or "revised the examples") and give a link to the page containing that work. This page makes it much easier for you to evaluate the contributions because you will not have to do any searching.

How?

You, as the instructor, will need to communicate to the students how they are going to build a valuable WikiGlossary. We claimed above that the students will need to be able to imagine the final WikiGlossary in order to understand what they will need to do to build it. We suggest that you build a skeleton of the WikiGlossary that contains the following components and ask the students to explore this skeleton on the first day. We have provided a sample skeleton [10], and we encourage you to copy from it liberally.

- A **MainPage** containing a Code of Conduct (i.e. a description of WikiNature) and a link to each of the following pages.
- A main page for the **WikiGlossary**, that will contain the alphabetized list of entries. This page should include instructions for adding and formatting new entries (and for naming those pages). There should also be links to a handful of interrelated sample entries that you have built, which model the quality of work expected as well as the naming and hyperlinking protocols. The term "function" seems particularly fertile and adaptable for modeling these standards.
- The **ToDo** page, where students list the items that need to be added and revised and where students can claim this work.
- The first few **Contributions** pages for the standing assignment, where the students give you links to the work they have done. This page should include a reminder to link to that work and to describe it.
- A **WikiHelp** page that contains information on the mechanics of adding to and editing your wiki such as any special instructions for typesetting, equation editing, and image adding.
- A designated space for the students to add the **BioPages** they create. You should list the content you expect students to add to their BioPages here and add your own BioPage as an example.

In addition to exploring this skeleton, the students should build their BioPages and add at least one new entry each as soon as possible. If you can provide a list of prerequisite terms, the students can practice building entries without having to wait for new content.

In the first week, the students will probably focus on adding new entries with minimal informal definitions or examples; but the value of the WikiGlossary comes from accrued wisdom, which lives in the informal definitions and examples. After the first week, we suggest that you help the students understand this deeper type of contribution by modeling such a contribution in class and valuing these contributions in the grading. It will help to articulate examples of deeper contributions, including (1) adding new intuitive definitions, i.e. intuitive definitions from multiple students in one entry, (2) adding examples that show new facets of the term/concept, (3) revising and expanding intuitive definitions to include new information from class, (4) adding commentary on what to keep in mind when working with a particular concept, (5) hyperlinking entries and adding some explanation of these links, and (6) reorganizing an existing entry so the exposition is clearer or more helpful. Post your articulation at the top of the WikiGlossary main page.

Why?

The experience of building a WikiGlossary will be quite different for students at different levels, and the utility of the product will depend heavily on the rest of your course. While the WikiGlossary will have built-in utility for students as a study aid, you should find additional motivation for your students to do this work that are in keeping with your own learning objectives.

We have three general suggestions for helping the students see the utility of their WikiGlossary. As above, you can make the WikiGlossary available to them during exams. Also consider creating exam questions that require the same processing skills by asking the student to create all or part of an entry for a new term. Finally, you can export (or print) the final draft as documentation of learning or a reference in the future.

We believe that a variation of a WikiTextbook project can enhance your next class, but we acknowledge that the endeavor takes some courage. We hope that the WikiGlossary example has given you the courage to try, and we hope that this paper has helped you see how you can make this idea your own.

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BIOGRAPHICAL SKETCHES

Brian Katz received his undergraduate degree from Williams College and his PhD from the University of Texas at Austin, where he learned to use inquiry-based course design. He has designed many classes around wiki projects and was invited to presented on the topic at the 2012 MAA PREP IBL Workshop. He is always looking for ways to build courses

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